Determinants of fecal continence in healthy, continent subjects: a comprehensive analysis by anal manometry, rectal barostat and a stool substitute retention test

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Abstract: BACKGROUND/AIMS: This study aimed to identify anal sphincter and rectal factors that determine anorectal filling sensations and continence during rectal filling in health. METHODS: Measurements of anorectal physiology were collected from 42 continent healthy subjects participating in a prospective trial. Rectal function and capacity were assessed by barostat. Anal sphincter functions were assessed by manometry. A validated stool substitute retention test was performed in which a viscous suspension was infused into the rectum at 60 ml/min to 1,500 ml. Multivariate regression was applied to identify physiologic factors that determine anorectal sensation and continence during rectal filling. RESULTS: The volume at which first awareness of rectal filling occurred associated with age ($p < 0.03$), rectal capacity ($p < 0.06$) and anal resting pressure ($p < 0.003$); urgency associated with rectal capacity ($p < 0.0007$), anal resting ($p < 0.04$) and squeeze pressure ($p < 0.02$); volume at first incontinence with rectal capacity ($p < 0.0001$) and squeeze pressure ($p < 0.04$) and the maximum volume retained were closely correlated with rectal capacity only ($p < 0.0001$). CONCLUSION: Anorectal filling sensations and continence in health require a rectal reservoir of adequate capacity and effective voluntary anal sphincter function. Complementary associations between continence, motor and sensory function indicate the presence of an adaptive mechanism that enables timely, appropriate responses to events that threaten fecal continence.

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Determinants of Fecal Continence in Healthy, Continent Subjects: A Comprehensive Analysis by Anal Manometry, Rectal Barostat and a Stool Substitute Retention Test

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Key Words
Fecal continence · Rectal barostat · Anal manometry · Retention test

Abstract
Background/Aims: This study aimed to identify anal sphincter and rectal factors that determine anorectal filling sensations and continence during rectal filling in health. ***Methods:*** Measurements of anorectal physiology were collected from 42 continent healthy subjects participating in a prospective trial. Rectal function and capacity were assessed by barostat. Anal sphincter functions were assessed by manometry. A validated stool substitute retention test was performed in which a viscous suspension was infused into the rectum at 60 ml/min to 1,500 ml. Multivariate regression was applied to identify physiologic factors that determine anorectal sensation and continence during rectal filling. ***Results:*** The volume at which first awareness of rectal filling occurred associated with age ($p < 0.03$), rectal capacity ($p < 0.06$) and anal resting pressure ($p < 0.003$); urgency associated with rectal capacity ($p < 0.0007$), anal resting ($p < 0.04$) and squeeze pressure ($p < 0.02$); volume at first incontinence with rectal capacity ($p < 0.0001$) and squeeze pressure ($p < 0.04$) and the maximum volume retained were closely correlated with rectal capacity only ($p < 0.0001$). ***Conclusion:*** Anorectal filling sensations and continence in health require a rectal reservoir of adequate capacity and effective voluntary anal sphincter function. Complementary associations between continence, motor and sensory function indicate the presence of an adaptive mechanism that enables timely, appropriate responses to events that threaten fecal continence.

Introduction

To understand the pathophysiology of continence problems, the mechanisms that govern anorectal sensation and fecal continence must be understood in health as well as disease.

Impaired anal sphincter function is the most common cause of fecal incontinence presenting to specialist clinics [1–3]; however, sphincter pressures are normal in a size-

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able minority of these patients [4–6]. Other factors that play a role in maintaining fecal continence include structural properties of the anorectum such as the capacity of the fecal reservoir [7, 8], the anorectal angle [9] and the integrity of the 'anal mucosal seal' [10, 11]. Effective rectal function must also be preserved including the accommodation of stool and timely, appropriate sensitivity during rectal filling [6, 12–14]. Any of these factors may be impaired in patients with fecal incontinence; but few studies have performed comprehensive testing of anal and rectal physiology in healthy, continent subjects. Moreover, all previous investigations have been limited by the lack of a sensitive, quantitative measure of continence function. As a consequence, the contribution and relative importance of the anal sphincter and the rectum in preserving fecal continence remains unclear. In particular, the role of sensation during rectal filling is controversial [13, 15–17].

To address the limitations of previous investigations, we developed and validated a novel stool substitute retention test [8]. This technique delivers a viscous suspension the consistency of thick molasses into the rectum by continuous infusion that stimulates the anus and rectum, and demands an active response of the study participant to maintain continence. In contrast to retention tests with continuous or bolus administration of fluid as described by Read et al. [4, 5] (on which this test was modeled), or weighted solids [18], this 'stool substitute retention test' is sensitive to variation in anal sphincter and rectal function within the 'normal range' that impairs continence function [8, 19, 20]. This study aimed to identify factors that contribute to rectal filling sensations and fecal continence in a well-defined cohort of healthy, continent subjects.

Materials and Methods

Subjects

Healthy, continent subjects were recruited by newspaper advertisement. Exclusion criteria included age greater than 55 years, history of pregnancy, positive pregnancy test, abdominal symptoms or bowel dysfunction, previous gastrointestinal surgery (except appendectomy), psychological disease or regular use of any medication. All subjects were required to sign consent to participate in these studies, which were approved by the ethical committee of the University Hospital Zurich. Sixty-three individuals responded to the advertisement, of which 49 fulfilled the study inclusion criteria (24 nulliparous females, 25 males) aged between 20 and 55 years. The prevalence of occult sphincter lesions and anorectal dysfunction in parous women and the elderly is high, and these groups were excluded to ensure a homogenous population.

Anorectal Studies

Subjects were instructed to avoid alcohol, provided with a standardized menu for 24 h before the study day and arrived for the anorectal studies following a minimum 4-hour fast. Clinical observations and digital rectal exam were performed. If residual stool was noted, the subject was asked to evacuate. A saline enema was administered if necessary; however, this bowel preparation was required on only two occasions.

Rectal Barostat

Measurements of rectal function and capacity were acquired using an electronic barostat (Distender series II, G&J Electronics Inc., Toronto, Ont., Canada) according to validated guidelines [21, 22]. A thin-walled, polyethylene barostat bag with infinite compliance up to a maximum volume of 800 ml (10 cm length) was connected to a silicon dual channel catheter (Mui Scientific, Mississauga, Ont., Canada). With the subject positioned in the left lateral 20° Trendelenbourg position, the bag was inserted such that the proximal end was 5 cm inside the anal verge and unfolded by brief insufflation of air. The minimal distending pressure (MDP) was measured and a conditioning distension was performed [22]. The volume of the rectum was measured at 2-mm Hg increments from 0 to 40 mm Hg (staircase distension). Then, rectal sensation was assessed during phasic bag distensions at 12, 24, 36 and 40 mm Hg performed in random order (air insufflation at 25 ml/s) [21]. Each distension period lasted 2 min, rectal volume measurements were acquired during the 2nd min with visual analog scale (VAS) rating rectal pressure, gas, urgency and pain [21].

Anal Manometry

Water-perfused manometry was applied consistent with published recommendations [23]. Resting anal pressure was recorded using a radial catheter during a slow pull-through. Maximal squeeze pressure increment above resting pressure was measured during a minimum of three voluntary anal contractions (maintained for 30 s) using a catheter with channels arranged at 1 cm intervals across the anal canal, placed near the region of maximum resting pressure.

Stool Substitute Retention Test

A retention test was performed as described previously using a viscous stool substitute (viscosity 10,000 cP at 37°C; Bristol Stool Score 5–6, the consistency of thick molasses) [8, 20]. A rectal introducer was placed such that the tip was 8 cm proximal to the anal verge. The subject was seated on a commode with a graduated cylinder placed to collect fluid lost from the rectum. A peristaltic pump (Watson-Marlow® 505S, Falmouth, UK) delivered the viscous suspension to the subject (standard enema used for MRI defecography at our institution) [24]. The rectal infusion proceeded at 60 ml/min to a maximum of 1,500 ml as established for the saline retention test [25]. Digital scales constantly monitored the volume delivered. The subject was instructed to retain the enema for as long as possible without leaking. Rectal sensations were noted during rectal filling. Volumes lost and volumes retained were recorded until the subject requested to stop the procedure, the stool substitute was exhausted, or volume loss exceeded that of the graduated cylinder (250 ml). The reproducibility of the stool substitute retention test has been demonstrated in a previous publication [8].

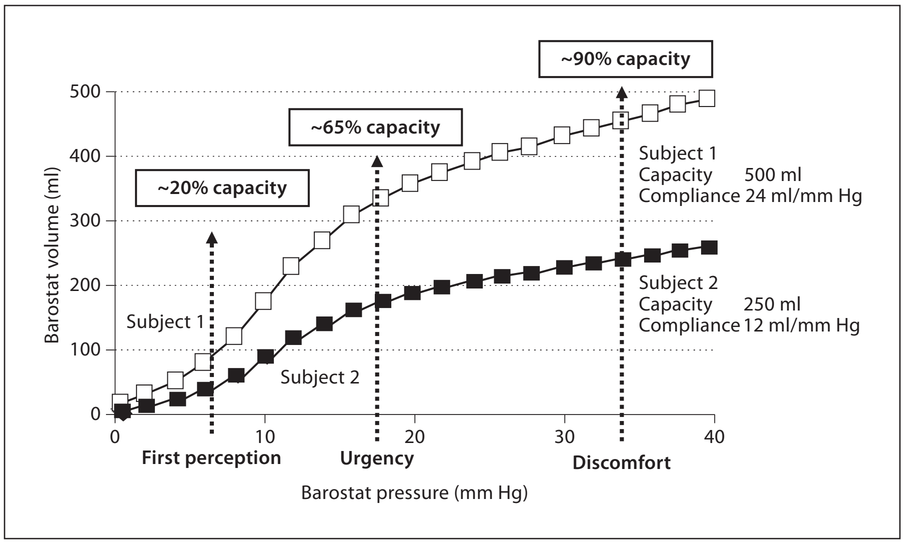

Fig. 1. Representative pressure-volume data from barostat studies in 2 subjects are presented. Rectal compliance was defined as the maximum slope of the pressure-volume curve. Asymptotic compliance was defined as the slope of the linear continuation. Rectal capacity was defined as the intra-bag volume at 40 mm Hg. Note that compliance increases in proportion to the capacity. This emphasizes the importance of structural factors in the rectal response to a volume load. Note also that, although rectal filling sensations are reported at very different absolute volumes, the percentage filling (normalized volume) at which sensations occur is identical. Moreover, sensations tended to be reported at characteristic points of the pressure-volume curve. First perception at the upward inflexion as rectal volumes begins to rise rapidly due to active wall relaxation. Urgency at the pressure-volume break as the rapid, active phase of rectal accommodation is completed.

Previous magnetic resonance imaging studies that used the stool substitute used in this work to assess rectal filling and defecation confirmed that residual stool is rarely found in the rectum in non-constipated individuals and revealed that the proximal extent of the 'stool substitute' is the junction between the sigmoid and descending colon [24]. Previous research with ambulatory anorectal manometry and clinical experience with barium enema studies have shown that the presence of a catheter in the anal canal does not impair continence function in healthy subjects [26].

Data Analysis

Barostat Measurements

The rectal pressure-volume relationship is characteristic (fig. 1). The data were fitted with a smooth logistic curve and a linear continuation after the break point. Rectal compliance was the maximum slope of the pressure-volume curve. Asymptotic compliance was the slope of the linear continuation. Barostat intra-bag volume at 40 mm Hg was rectal capacity (note: rectal volume increased only slightly at supraphysiologic levels, and validation studies indicate that any volume above ~30 mm Hg distension pressure would produce similar results [8]). In addition, to unadjusted volume measurements acquired during distensions, barostat bag volume at any pressure was also expressed as percentage normalized rectal volume, i.e. the fractional rectal filling relative to rectal capacity [(rectal capacity – measured volume)/rectal capacity]. Normalized rectal volume is a dimensionless parameter, analogous to strain measured by impedance planimetry [27, 28]. This measurement is independent of variation in rectal capacity and, therefore, facilitates comparisons between patients [8].

Reporting of rectal sensations by VAS is known to show high variance between individuals; however, for a given individual and sensation, VAS measurements increase with intra-balloon pressure in an approximately linear relation [21]. To stabilize variance of VAS measurements, the raw VAS scores were offset log transformed, an aggregate score of rectal sensations (rectal pressure, gas, urgency and pain) was calculated, and the increase in VAS score per unit pressure increase was calculated. In this manner, an estimate of the aggregate VAS score at any pressure can be computed. This procedure results in robust summary measurements for inclusion of rectal sensitivity in regression analysis [8, 19, 20].

Anal Manometry

Anal pressures were measured relative to rectal pressure. Resting anal pressure was the average peak pressure from the four radial channels during pull-through. Squeeze pressure was recorded during 30 s of voluntary anal contractions from four channels arranged at 1-cm intervals through the anal canal. Squeeze pressure was the average increment above resting pressure from a minimum of three attempts. During voluntary anal contraction, pressure decreases due to fatigue and a robust regression was fitted to these data. The 'fatigue rate' was the gradient of the regression. Squeeze duration was the time in seconds for fatigue to the baseline resting pressure by a robust regression [19]. Values over 120 s were considered stable over the period of observation.

Retention Test

During rectal filling, the volume infused at first sensation and urgency, volume at first incontinence and maximum retained volume were recorded (fig. 2). The presence of a 'reservoir volume' was assessed in subjects with ≥3 episodes of volume loss. A stable 'reservoir volume' was present if, at volumes approaching the maximum volume retained (<10%), ongoing volume loss approximated ongoing volume delivered and the retained volume remained constant (fig. 2) [8].

Statistics

Demographic data and quantitative variables showed nonparametric distribution and are presented as median (interquartile range). The range is provided also to demonstrate the wide normal variation. Multiple linear regressions were performed taking the stool substitute retention test results as dependent variables and demographic data and physiologic measurement as independent covariates. To explore which factors influence sensation and continence during rectal filling, we included age, rectal capacity, compliance, asymptotic compliance, resting pressure, squeeze pressure and squeeze duration as covariates in multiple linear regression models. For each model, the percent of the variance in the dependent variable (e.g. volume at first incontinence) explained by the multiple regression model was assessed. The F-statistic indicates the ability of the model to predict the dependent variable on a linear scale. If the model explained a significant proportion of the variance, then the contribution of individual variables was calculated. The t ratio expresses the strength of this association on a linear scale. Potentially confounding interactions between these variables (multicolinearity) were not present for any of the models presented.

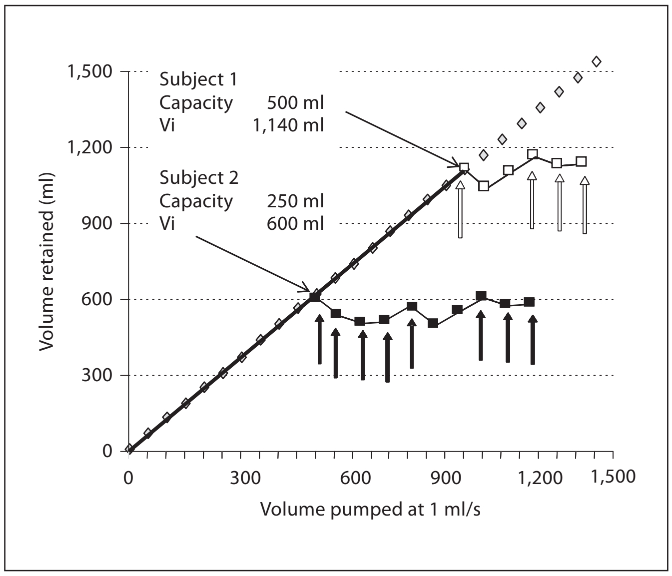

Fig. 2. Representative stool substitute retention test measurements from the 2 subjects presented in figure 1. Deviation of the volume retained (continuous line) from the volume infused (dotted line) indicates incontinence episodes. In both cases when the volume at first incontinence (Vi) is reached, further volume loss approximates ongoing volume infused and the retained volume remains stable. Thus, a stable 'reservoir volume' is observed and this volume is proportional to rectal capacity. Note that, in both cases, Vi is larger but increases in proportion with rectal capacity.

Results

Physiologic measurements were performed in 49 subjects; however, 5 withdrew consent having failed to tolerate study procedures and 2 subjects experienced vasovagal para-syncope during the retention test. Thus, 42 participants (19 female, 23 male) completed the comprehensive anorectal assessment. There was no significant difference in demographic characteristics between patients that completed the studies and those that did not. Results are summarized in table 1.

Barostat Measurements

Rectal compliance was 24 ml/mm Hg (16–31 ml/mm Hg) and rectal capacity at 40 mm Hg intra-bag pressure was 390 ml (209–503 ml). There was a positive association between capacity and compliance ($r^2 = 0.58$, $p < 0.01$), such that subjects with a large rectum had higher rectal compliance (fig. 1). Asymptotic compliance was 5.8 ml/mm Hg (3.0–8.7 ml/mm Hg) without association to rectal capacity or compliance.

Rectal VAS increased as a function of intra-bag pressure for rectal pressure, gas, urgency, pain and aggregate sensations ($p < 0.001$). No association was found between rectal sensation and unadjusted volume measurements or compliance; in contrast, aggregate VAS scores increased with normalized rectal volume ($r^2 = 0.30$, $p < 0.01$). In terms of normalized rectal volume (i.e. percentage filling), rectal filling sensations of perception (pressure), gas, urgency and pain occurred at median 19% (6–28%), 30% (27–83%), 65% (36–83%) and 85% (80–100%) of rectal capacity, respectively (fig. 1).

Anal Manometry

Resting anal pressure (anal sphincter tone) was 95 mm Hg (28–122 mm Hg) in these healthy subjects. Squeeze pressure increment above resting pressure (voluntary anal sphincter contraction) was 178 mm Hg (36–358 mm Hg), and squeeze duration (time sphincter pressure held above resting value) was 94 s (range 7 to >120 s). Sphincter pressures were similar in men and women. Resting pressure was stable, but voluntary squeeze pressure decreased slightly with age (data not shown).

Table 1. Summary of results

Demographic characteristics	Median	Range	
Age, years	38	20–54	
Males/females	23/19		
Physiologic measurements	**Median**	**Interquartile range**	**Full range**
Rectal barostat			
Rectal capacity at 40 mm Hg, ml	390	315–468	209–503
Rectal compliance, ml/mm Hg	24	16–31	7–39
Asymptotic compliance	5.8	4.7–6.8	3.0–8.7
Anal manometry			
Resting pressure, mm Hg	95	79–122	28–236
Squeeze pressure, mm Hg	178	119–222	36–358
Squeeze duration, s	94	54 to >120	7 to >120
Retention test			
Volume at first sensation, ml	160	100–225	30–420
Volume at urgency, ml	550	350–660	150–1,250
Initial incontinence, ml	710	510–870	180–1,500
Maximum retained, ml	830	530–1,080	180–1,500

Retention Test

During rectal filling, first awareness was sensed at 160 ml (range 100–220 ml), fecal urgency at 550 ml (350–660 ml), first incontinence occurred at 710 ml (510–870 ml), and the maximum volume retained was 830 ml (510–1,080 ml). At least three episodes of volume loss occurred during the retention test in 37/42 participants, and a stable 'reservoir volume' that approximated the maximum volume retained was observed in 32 (86%) of these subjects (fig. 2).

Multiple Regressions

First Awareness of Rectal Filling

The multiple regression model explained 48% of the variance in the threshold volume at which the patient first became aware of rectal filling ($F = 3.7$, $p < 0.0039$). Individual variables that contributed to the model included a negative correlation with age ($t = 2.4$, $p < 0.03$) such that the volume at which first awareness was sensed decreased with increasing years, and positive correlations with rectal capacity ($t = 1.9$, $p = 0.06$) and anal resting pressure ($t = 3.3$, $p < 0.003$) such that the volume at which first awareness was sensed increased with rectal capacity and anal resting pressure. External anal sphincter function (squeeze pressure and duration) did not contribute.

Fecal Urgency during Rectal Filling

The multiple regression model explained 51% of the variance in the threshold volume at which the patient first experienced the call to stool ($F = 3.5$, $p < 0.0041$). Individual variables that contributed to the model included a borderline negative correlation with age ($t = 1.9$, $p = 0.06$), and positive correlation with rectal capacity ($t = 3.7$, $p = 0.0007$), anal resting pressure ($t = 2.2$, $p < 0.04$) and squeeze pressure ($t = 2.6$, $p < 0.02$) such that the volume at which urgency was sensed increased with rectal capacity and anal sphincter pressures. Squeeze duration did not contribute.

Volume at First Incontinence and Maximum Volume Retained

The multiple regression model explained 33% of the variance in the threshold volume at which the patient experienced first incontinence ($F = 2.2$, $p < 0.04$) and 72% of the maximum volume retained ($t = 4.5$, $p < 0.0001$). Individual variables that contributed to the model included positive correlations with rectal capacity ($t = 4.2$, $p < 0.0001$), and squeeze pressure ($t = 2.2$, $p < 0.04$). Demographic variables and anal resting pressure did not provide independent contributions to the regression models.

In all the regression analyses, rectal compliance covaried with rectal capacity, such that subjects with large rectal capacity have higher rectal compliance; however, rectal capacity dominated in all regression analyses (i.e. improved the model more than rectal compliance). Thus, only rectal capacity showed an independent association with retention test measurements and is presented.

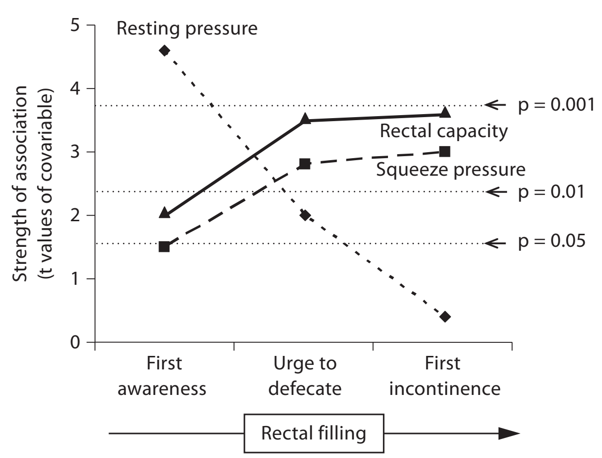

Fig. 3. Relative importance of anal sphincter function and rectal capacity on sensation and continence during the stool substitute retention test as assessed by the strength of association on covariant analysis (t values). First awareness of rectal filling was closely correlated to resting pressure and to a lesser extent to rectal capacity. As filling continued, the importance of resting pressure to sensation decreased. At the same time, the association of squeeze pressure and rectal capacity to anorectal sensation and continence function increased.

The interaction of anal sphincter and rectal capacity on filling sensation and continence as assessed by the stool-substitute retention test is summarized in figure 3.

Discussion

This study acquired comprehensive physiological measurements of anorectal function by rectal barostat and anal manometry together with objective measurements of filling sensation and continence by a validated 'stool substitute retention test'. Covariate analysis revealed three variables that were independently associated retention test measurements: rectal capacity, anal resting pressure and squeeze pressure. These observations provide insight into the mechanism by which the anal sphincter and the rectum maintain fecal continence in healthy, continent subjects.

There was a close correlation between rectal capacity (barostat volume at 40 mm Hg) [8], and the volume at which filling sensations were reported and first incontinence occurred. Moreover, at volumes close to the maximum volume retained, ongoing volume loss closely approximated ongoing volume delivered and the retained volume remained constant (fig. 2). These observations indicate the presence of a stable 'fecal reservoir' in continent subjects, the volume of which appears to be determined by the 'structural capacity' of the distal colorectum. Normal daily stool volume (150–250 ml) is considerably smaller than the median reservoir volume (830 ml) for stool substitute, suggesting the presence of a large functional reserve in health. In contrast, for patients with fecal impaction, the volume of rectal contents may approach the capacity of the rectum, with further filling leading to 'overflow' incontinence from the fecal reservoir even in the presence of normal anorectal function [29]. Similarly, continence problems are common in patients with reduced rectal capacity despite normal fecal volume (e.g. due to chronic rectal inflammation) [12, 30, 31]. No independent association was found between rectal compliance and continence function as assessed by the retention test and rectal capacity dominated compliance in regression analysis. This finding does not exclude the importance of rapid and appropriate rectal relaxation during rectal filling (fig. 1), and previous studies using the same methodology have shown that patients with continence problems have lower rectal compliance independent of rectal capacity [20].

The important role of anal sphincter function in continence function was confirmed and an association between anal sphincter pressures and filling sensations was revealed. Previous studies have related the clinical presentation of fecal incontinence to the specific pattern of sphincter weakness. Patients with passive or stress incontinence have low resting anal pressure (largely generated by the internal sphincter), whereas those with urge incontinence have low squeeze pressure (generated by the external sphincter) [1–3]. This study confirms that squeeze pressure has an important role in continence function across a wide range of pressures in healthy, continent subjects. In contrast, resting pressure was associated with anorectal sensitivity (discussed below) but did not affect the volume at first incontinence, suggesting that this does not play a role when normal anorectal sensitivity and effective external anal sphincter function are preserved. No association between the fatigue rate or squeeze duration (the ability to maintain squeeze pressure over time) and continence was found in this study using a viscous stool substitute; however, previous work has shown that these factors are important for retention of liquid [19].

Similar to continence function, covariant analysis revealed associations between the volumes at which 'first sensation' and urgency were sensed during rectal filling, rectal capacity and anal sphincter pressures. Not only rectal distension but also anal sphincter function had effects on sensation during rectal filling. Subjects with a small rectal capacity had lower threshold volumes for first sensation and urgency and also experienced more intense sensations at any given volume. The threshold volume at first awareness also correlated strongly with resting anal pressure ($p < 0.001$). As filling progressed, the volume at which the urge to defecate was sensed correlated with resting pressure ($p < 0.05$), squeeze pressure ($p < 0.05$) and rectal capacity ($p < 0.01$). At still higher volumes, first incontinence correlated only with squeeze pressure ($p < 0.02$) and rectal capacity ($p < 0.01$).

It is clear from these findings that a close association exists between anorectal structure, function and sensation. Observational studies have shown that first awareness is sensed early during rectal filling as the internal anal sphincter responds to the buildup of pressure in the proximal anal canal [32, 33]. At this stage, voluntary contraction of the external anal sphincter is required to prevent fecal loss during 'anal sampling' (reflex relaxation of the internal anal sphincter) and promote rectal relaxation to accommodate stool [13, 34, 35]. The urge to defecate is sensed at higher volumes as intrarectal pressure increases. At this stage, voluntary contraction is required to suppress rectal contractions and defer defecation until a socially appropriate opportunity arises [13, 35–37]. Thus, first awareness and the urge to defecate occur at specific stages during rectal filling when a specific component of the continence mechanism is threatened and a voluntary response is required. The interaction between rectal capacity, sphincter function and sensation provides a mechanism that could mediate the timely, appropriate response to events during rectal filling. The ability of subjects to maintain continence despite wide variation in anorectal function implies that this system is mediated by not only reflex responses but also feedback mechanisms and conditional learning. Such a mechanism could explain anorectal hypersensitivity in patients with reduced rectal capacity or weak anal sphincter function. In these patients, raised awareness of rectal filling represents an appropriate, adaptive and learned response to the increased risk of incontinence. Conversely, poorly matched anorectal sensory and motor function may impair continence function [32] either because reduced sensitivity fails to signal the presence of stool in the rectum, or because increased sensitivity is associated with severe urgency, frequent defecation and even incontinence [7, 12, 38, 39]. Should abnormal continence function be caused by abnormal sensation, then incontinence and other disorders of defecation should be treatable by behavioral training. Indeed, this is considered to be the physiological basis for the efficacy of biofeedback therapy, and studies demonstrate that changes in anorectal sensitivity are closely related to treatment success [40–42].

The study cohort covered an age range from 20 to 55 with an equal representation of males and nulliparous females to ensure a homogenous group with low incidence of occult dysfunction. The relative strength of associations between rectal capacity, anal function and continence may be somewhat different in elderly (>55 years) individuals and parous females. Most importantly, these results are likely to be grossly disturbed in patients with clinical disorders of anorectal function and continence. The validity of the stool substitute retention test is also key. No standard measurement of fecal continence is available; however, the close associations between measurements of continence, rectal barostat and anal manometry findings suggest that this investigation provided meaningful results. The infusion of a stool substitute stimulates both the anal canal and the rectum and challenges the continence mechanism in a more physiological fashion than methodologies that stimulate the rectum or anus separately.

In conclusion, this study provides objective evidence that normal continence function requires a rectal reservoir of adequate capacity and effective external sphincter pressure. Similarly, sensation during rectal filling was associated with the effectiveness of the anorectal continence mechanism. First sensation during rectal filling occurred as internal anal sphincter function was threatened, and the urge to defecate was triggered as external sphincter function was threatened. These associations provide novel insights into the sensitive, adaptive sensorimotor mechanism that facilitates the timely, appropriate response to events during rectal filling and maintains fecal continence.

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